STRUCTURAL CALCULATION FOR INLET STRUCTURE OF DIVERSION TUNNEL

[UPPER TRISHULI-1 HEP (216MW)]

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FOR APPROVAL

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Project

Upper Trishuli-1 HEP (216MW)

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1 Statement Of Calculation

1.1 Project Profile

The diversion tunnel (abbreviation “D/T”) is located on the right bank of Trishuli River. The flow cross section is a reversed “D” shaped type (rectangular shape plus an arc section) with a width of 5.00m, vertical sidewalls with a height of 3.50m and an arc shaped roof top with a radius of 2.83m. The elevation of the inlet is EL. 1244.50m, and the elevation of outlet is EL. 1231.00m. The length of diversion tunnel is about 413.04m and the longitudinal slope is 3.32%.

The inlet structure of D/T is reinforced concrete structure with stop-log, the invert elevation is EL.1244.5m, and the top platform elevation is EL.1250.5m. The length of inlet structure is 9.5m in flow direction (from the chainage D0-003.50~D0+006.00), and the width is 8m perpendicular to flow direction. The opening size of closure gate is 5m×5m (width × height).

The inlet structure's longitudinal profile and plan is shown in Fig. 1.1.1~1.1.2

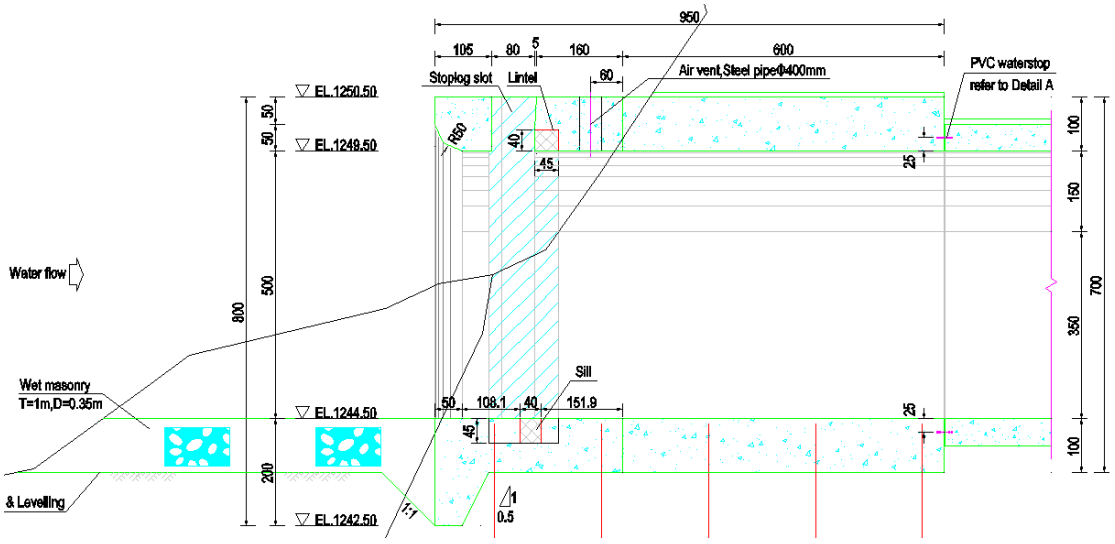

Figure 1.1.1 Profile Section of inlet structure of D/T (unit: cm)

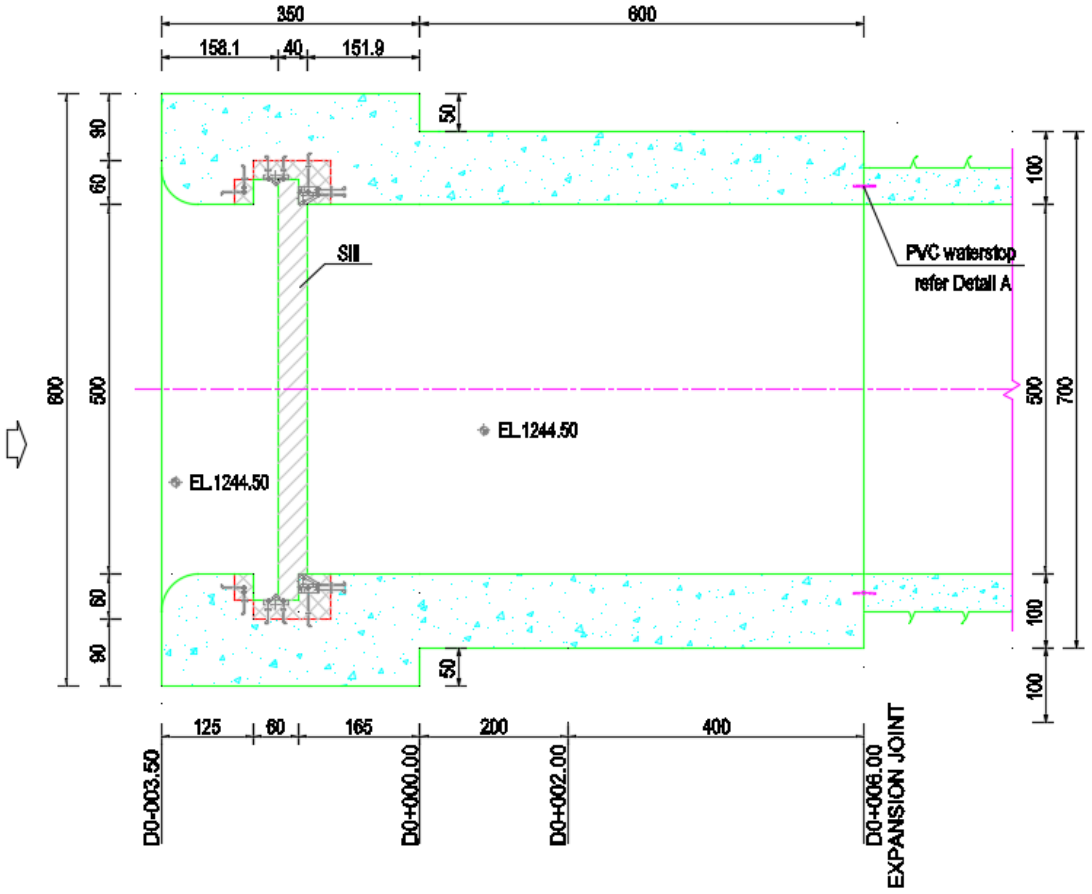

Figure 1.1.2 Plan at EL. 1247.0m of inlet structure of D/T (unit: cm)

1.2 Design Stage

Design stage of the project is for detail design stage.

1.3 Calculation Contents And Purpose

The purpose of this calculation is providing a basis for structure reinforcement by force analysis and internal force calculation of the inlet structure.

2 Reference Document

2.1 Rules And Regulations

(1)Building Code Requirements for Structural Concrete and commentary (ACI318-11);

(2)Strength Design for Reinforced-Concrete Hydraulic Structure, EM1110-2-2104.

2.2 Technical Documents

(1) General Layout of Diversion Tunnel, UT1-C-010-CVL-DG-42001;

(2) Outline of Inlet Structure of Diversion Tunnel, UT1-C-010-CVL-DG-42004;

(3) Design Optimization Proposal of Diversion Works Rev. D, UT1-C-000-CVL-DD-40001, released at 29th Nov.2021.

3 Calculation Process

3.1 Basic Information

3.1.1 Material Characteristics and Calculation Parameters

(1) Concrete

a) Class E (Cylinder compressive strength is 24MPa)

Volume weight of reinforced concrete: 25.0kN/m^3;

b) Elastic modulus and Poisson's ratio is shown in Table 3.1.1.

Table 3.1.1 Elastic modulus and Poisson's ratio

Elastic Modulus E_c (MPa)	Poisson's Ratio
2.3×10^4	0.2

(2) Reinforcement

a) Yield strength of deformed bar: 500MPa;

b) Yield strength of round bar: 280MPa;

c) Elastic modulus: 200,000MPa;

(3) Water

Volume weight of water: 9.8kN/m³;

3.1.2 The value of water level in different stages

Value of water level is shown in Table 3.1.2.

Table 3.1.2 Water Level in Different Cases

Working Condition	The water level at D/T Inlet	Remark
Normal condition- Overflow of U/S cofferdam	EL.1260.24m	Upstream water level (20 year return period flood)
Gate Closing	EL.1250.17m	Plugging(Normal water level)

Note: prior to D/T plug, the stoplog gate of D/T will be closed, at that time, the weir/dam is complete, the river flow will be discharged through the orifices of weir/dam. At that time, in case of 20-year return period flood with corresponding flood flow of 1827.2m³/s (refer to DOP of diversion works, Rev.D, Table 3.2.1-1), the upstream water level of weir/dam is 1247.6m, and the water level of D/T intake is 1250.17m back calculated from weir/dam location.

3.1.3 Water pressure of gate

In gate closing condition, the water pressure of gate is $0.5x9.8x(1250.17-1244.5)^2x5.6=882.16$KN. The water pressure is transmitted to the inlet structure body by gate slot.

3.1.4 Earthquake Parameters

EPGA of tunnel portal is 0.112g, horizontal seismic acceleration for pseudo static analysis is 0.112gx(2/3) = 0.075g, vertical seismic acceleration for pseudo static analysis is 0.075g x(2/3)=0.050g.

3.2 Load factor

The calculation is made in accordance with the modified ACI318 method in EM1110-2-2104.

Case 1: normal operation $U = 1.2D + 1.6(L+F)$

Case 2: gate closing $U = 1.2D + 1.6(L+F)$

Case 3: normal operation + earthquake $U = 1.2(D+F) + 1.0E+1.0L$

Where,

D ——internal forces and moments from dead loads;

L——internal forces and moments from live loads;

F——fluid pressure;

E——earthquake force;

4 Calculation model

The 3D FEM calculation model is divided into two groups: concrete and bedrock, with two materials in total. The structure of intake adopts class E concrete. The calculation model adopts hexahedral meshing. The number of nodes and elements of total model is 18801 and 15312. The upstream and downstream length of foundation of intake is taken as 16m respectively, and the height of foundation is also 16m. A right-handed coordinate system is used for the calculation. The y-axis is the direction of the flow and positive direction points upstream. The z-axis points up.

The calculation model is shown in Fig. 4.1~4.2.

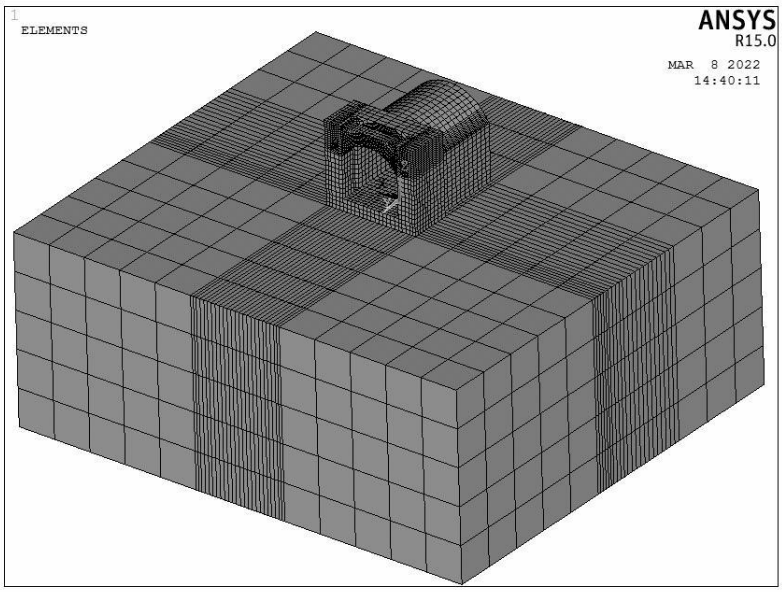

Figure 4.1 Overall FEM model

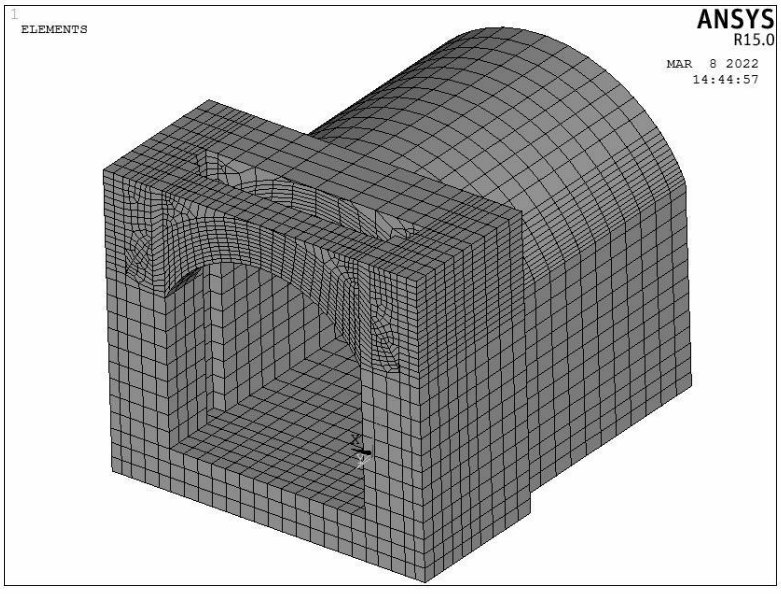

Figure 4. 2 FEM meshing of concrete structure

5 Calculation result

5.1 Basic formula of structural reinforcement calculation

For mass concrete structures, such as concrete around steel spiral and draft tube, reinforcement shall be made according to elastic stress method. Calculating the reinforcement according to the formula (Fig.5.1.1).

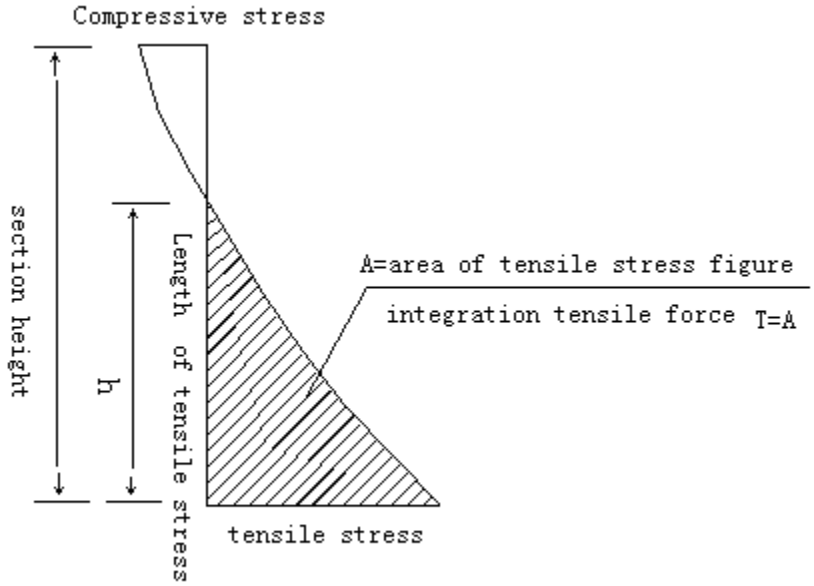

Figure 5.1.1 Schematic diagram for tensile force integration

$$A_s = \frac{T}{\phi f_y} \tag{5.1.1}$$

$$T=A=b\int_0^h \sigma \, dx \tag{5.1.2}$$

Where,

A_s ——Area of non-prestressed longitudinal tension reinforcement;

f_y——Specified yield strength of reinforcement;

φ——Strength reduction factor, φ=0.9;

T——Tensile force;

A——The area of tension stress;

h——The height of tension stress;

b ——The width of tension stress;

σ —— Tension stress on section.

5.2 Calculation result

According to FEM calculation, in normal operation condition and normal operation + earthquake condition, inlet structure is immersed in water, and the surface and internal water pressure cancel each other out. So the gate closing condition is control condition. The following results are based on gate closing condition.

5.2.1 Deformation and stress results of total structure

The deformation and stress results of inlet structure is shown in Fig.5.2.1~Fig.5.2.4.

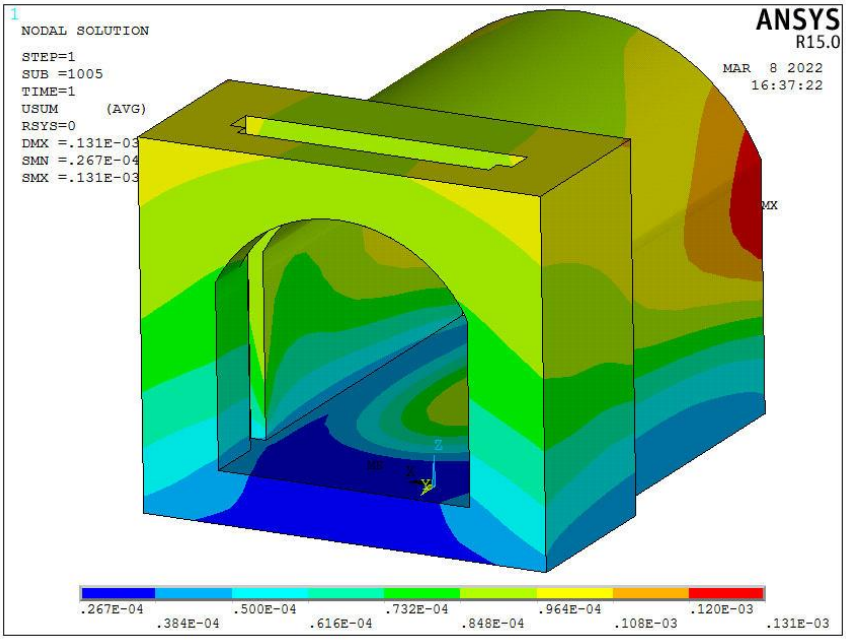

Figure 5.2.1 Total displacement of inlet structure (unit: m)

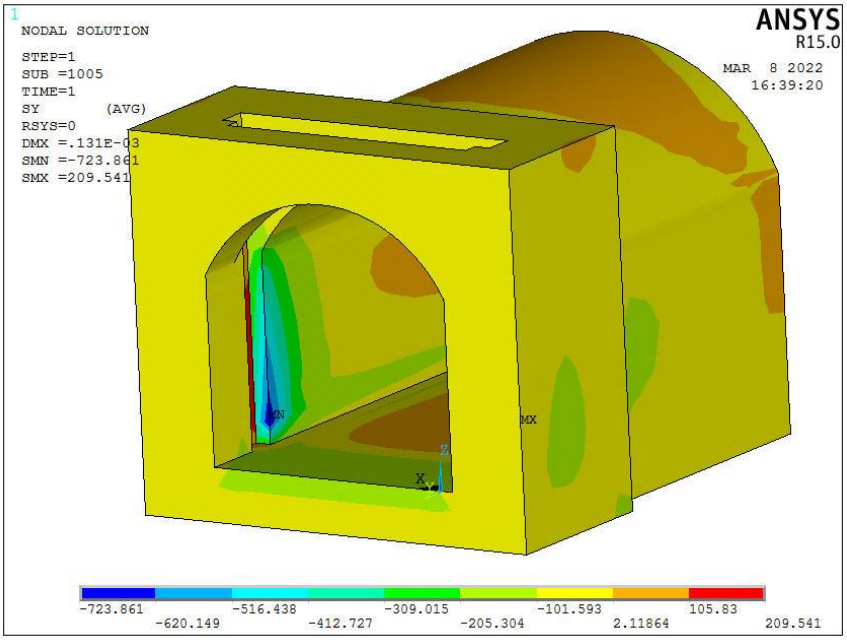

Figure 5.2.2 x direction stress contour (unit: KPa)

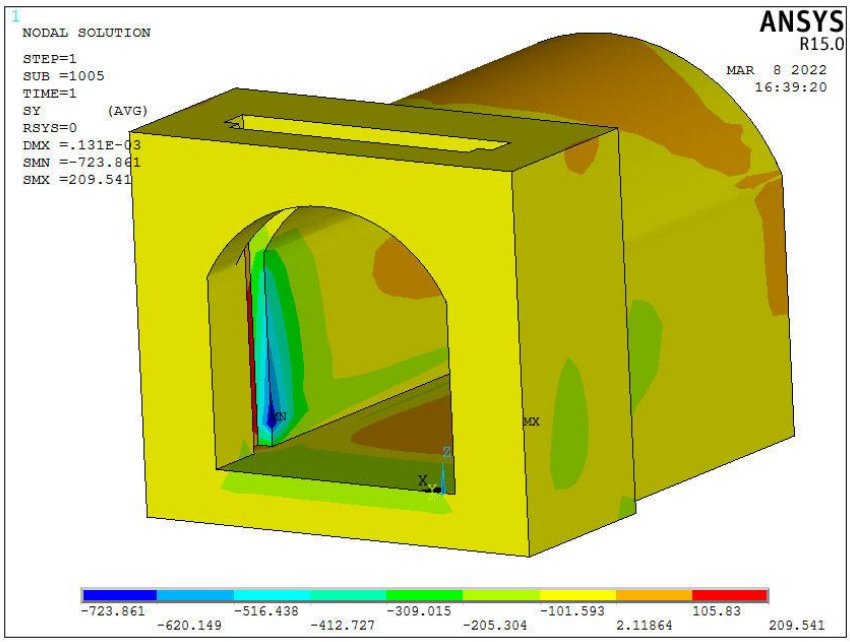

Figure 5.2.3 y direction stress contour (unit: KPa)

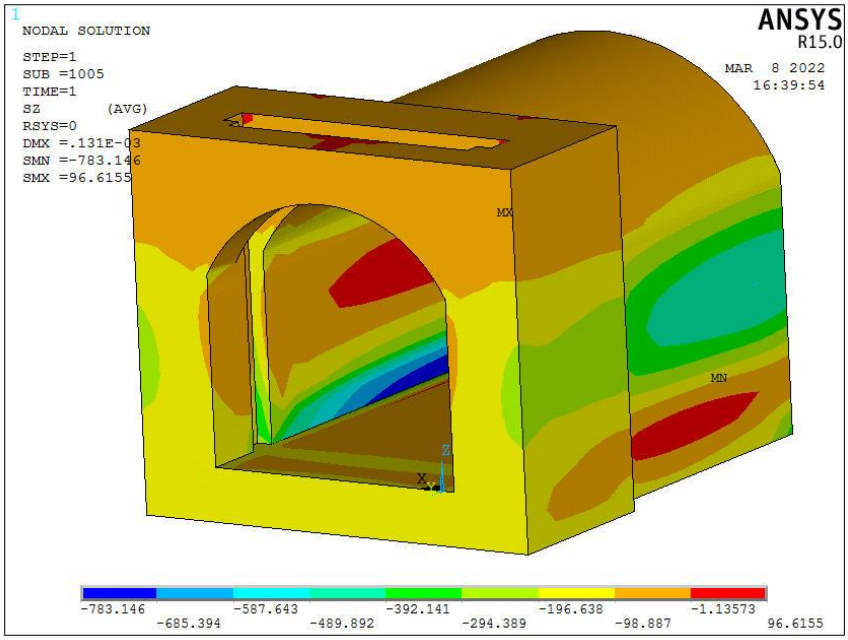

Figure 5.2.4 z direction stress contour (unit: KPa)

5.2.2 Calculation section

Two typical sections of gate slot and three typical section of inlet structure side walls and invert are chosen for internal force calculation and reinforcement.

Figure 5.2.5 typical sections of gate slot

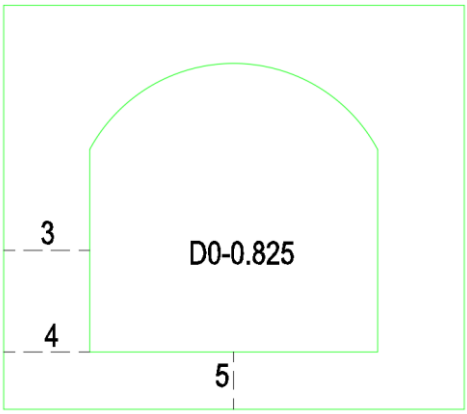

Figure 5.2.6 typical sections of side wall and floor

5.2.3 Stress integral and reinforcement

Stress integral is shown in Fig. 5.2.7-5.2.11. Reinforcement result is shown is table 5.2.1.

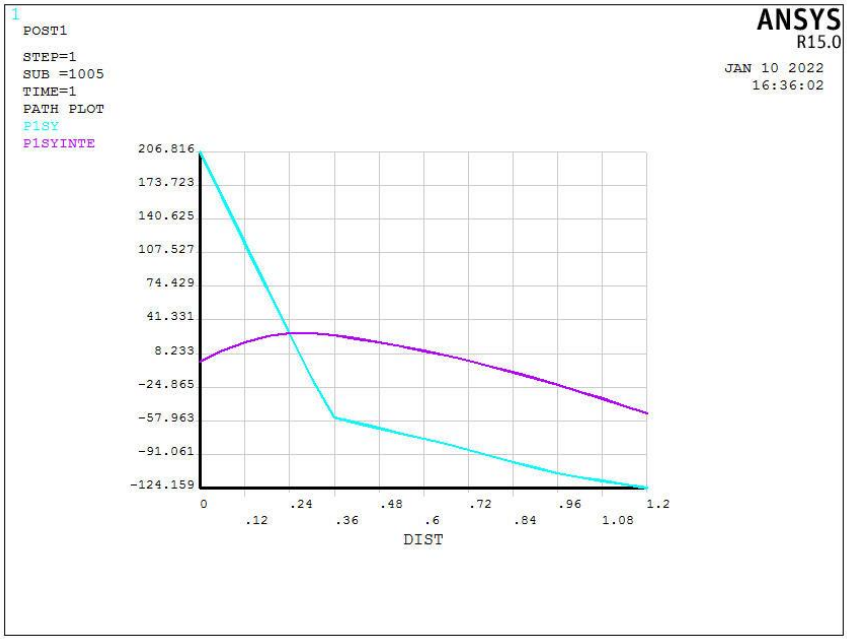

Figure 5.2.7 Stress and tensile force of section 1

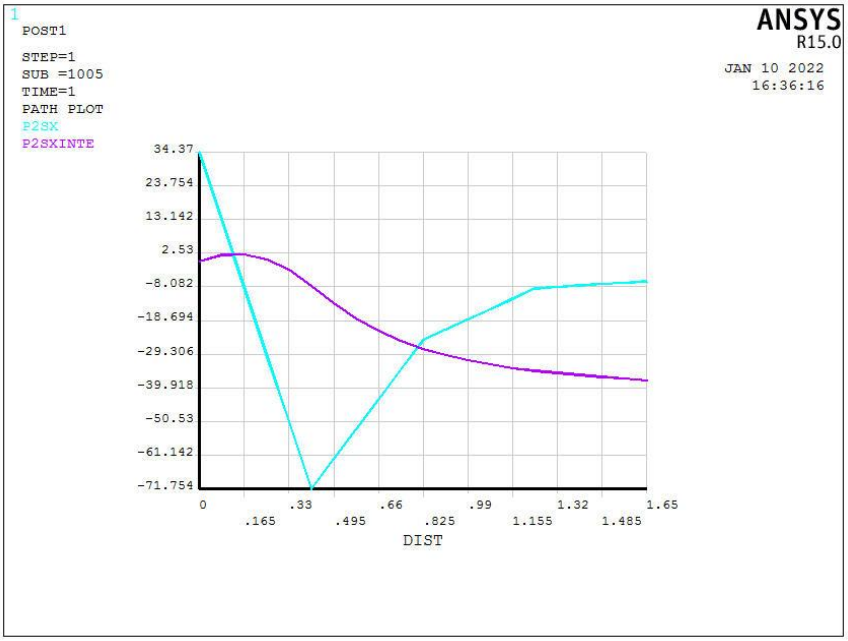

Figure 5.2.8 Stress and tensile force of section 2

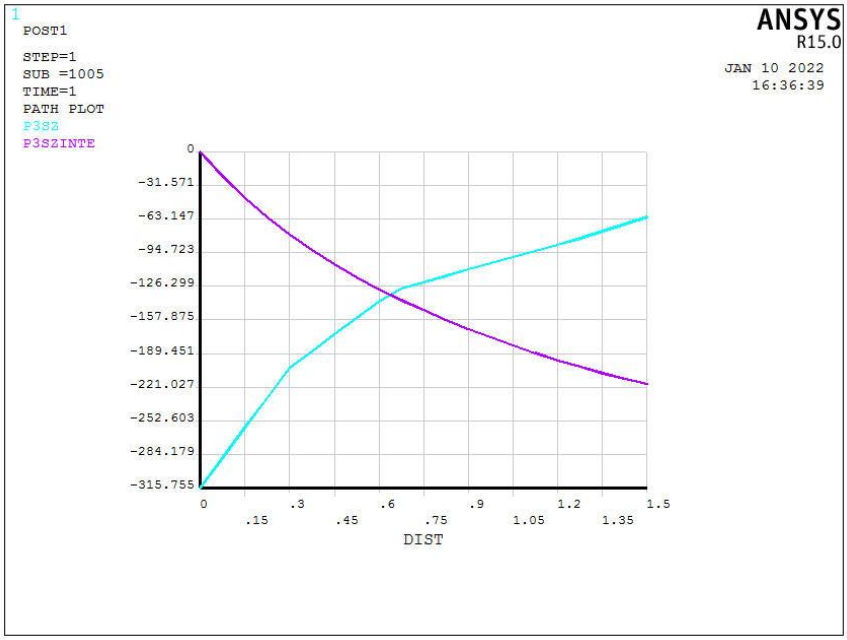

Figure 5.2.9 Stress and tensile force of section 3

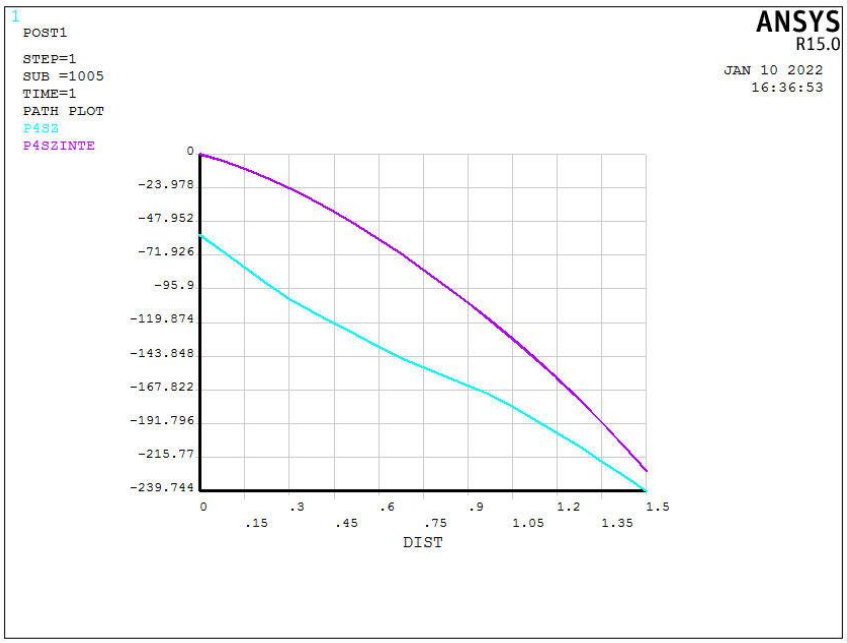

Figure 5.2.10 Stress and tensile force of section 4

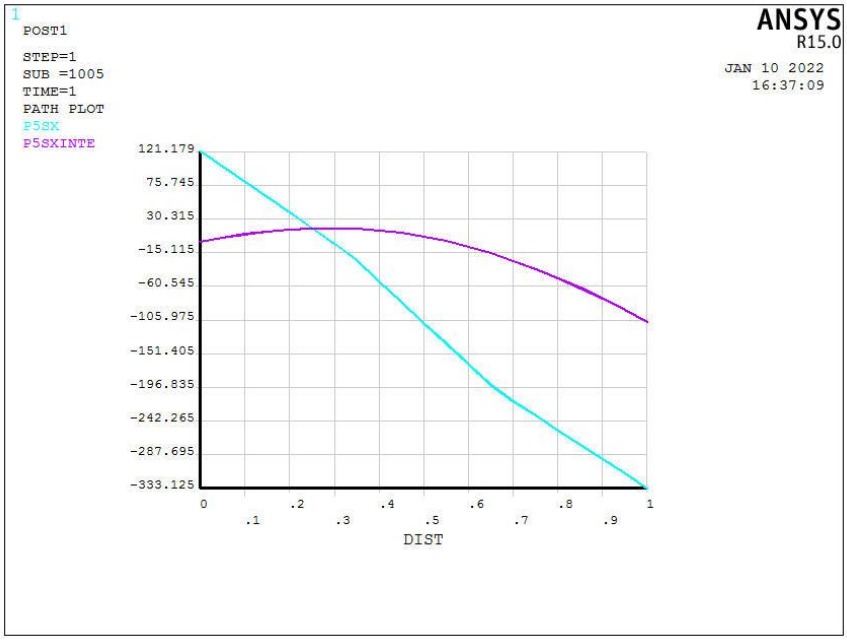

Figure 5.2.11 Stress and tensile force of section 5

Table 5.2.1 Reinforcement calculation

Section	1	2	3	4	5
Tensile force (kN)	40.4	2.6	Full-section compressed	Full-section compressed	28.2
Yield strength of deformed bar （MPa)	500	500	500	500	500
Strength reduction factor of deformed bar	0.9	0.9	0.9	0.9	0.9
Minimum reinforcement ratio	0.0014	0.0014	0.0014	0.0014	0.014
Selected reinforcement	D25@200	D25@200	D20@200	D20@200	D20@200

6 Reinforcement sketch

Reinforcement sketch of gate slot, side wall and floor are shown is figure 6.1~6.2.

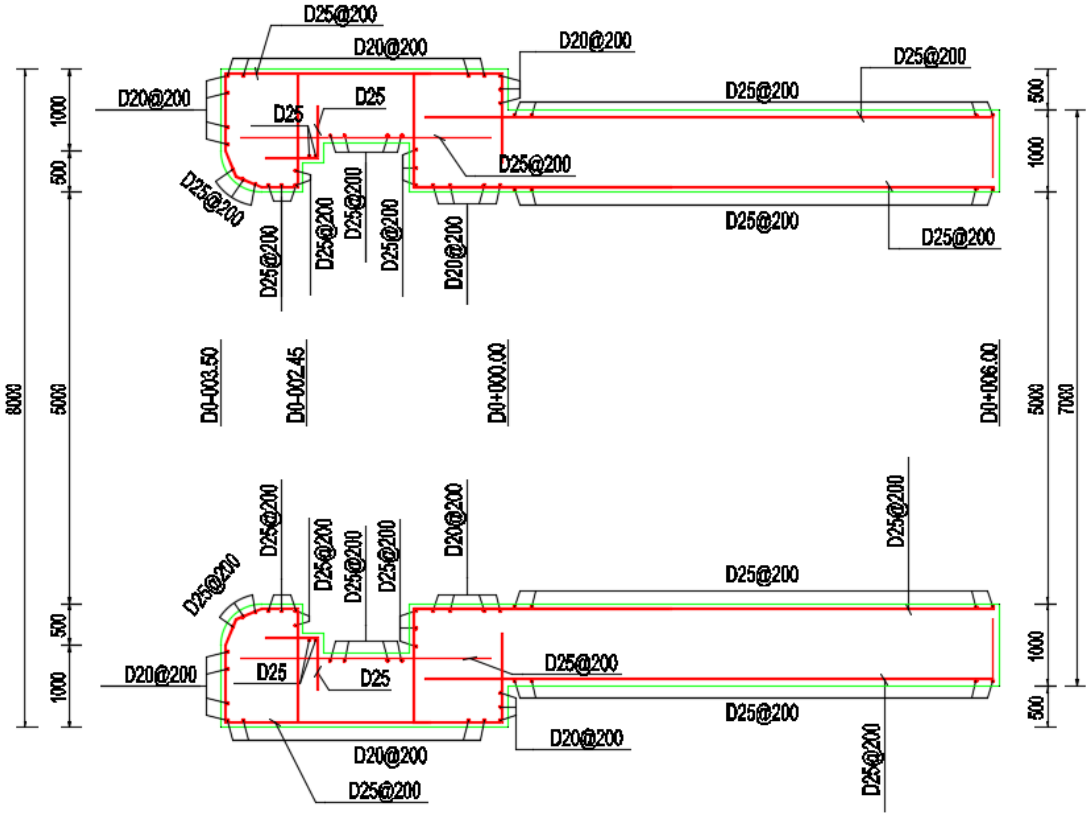

Figure 6.1 Reinforcement sketch of gate slot

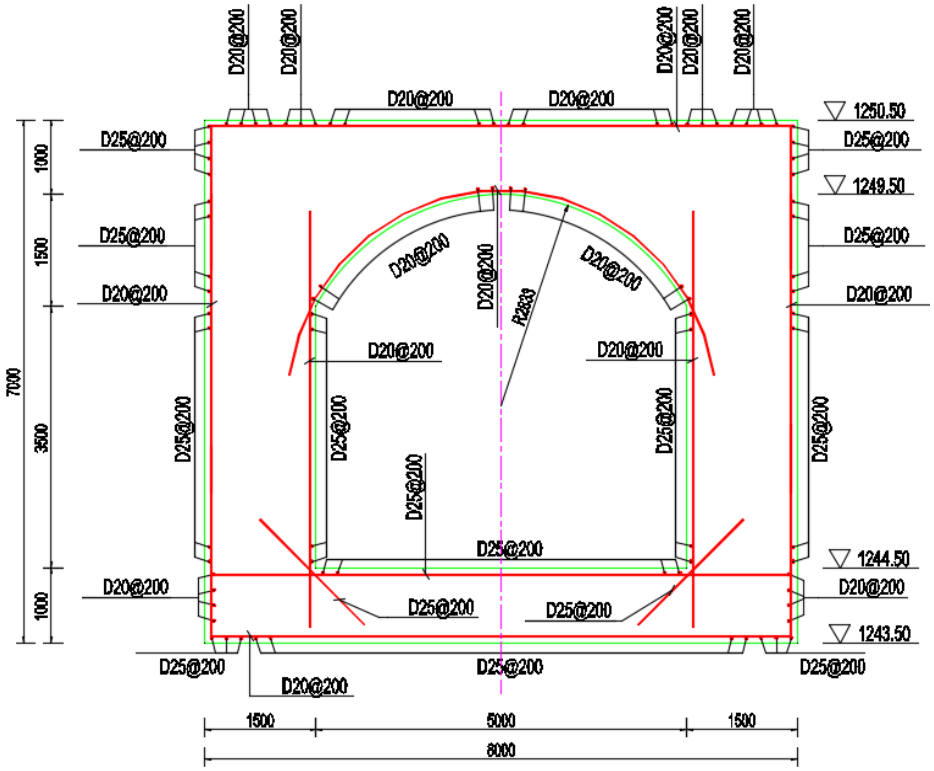

Figure 6.2 Reinforcement of side walls and invert